designated **113**. Generally speaking, the fuel **130** may pass either inside or outside the tubes **113**, with the removed oxygen occurring in the other of the two. This requires the membrane filter **112** to at least be in direct contact with the fuel **130**. In the illustrated embodiment, the fuel **130** flows into the shell region via fuel inlet **120** and over the membrane filter **112** on the exterior surface of the tubes **113**. Correspondingly, the oxygen removed from the fuel occurs and collects within the tubes **113**, which in turn connect to a manifold **117** containing the removed oxygen outlet **124**. This construction maximizes the area of membrane filter **112** contacted by fuel **130** and minimizes the volume of shell **111**, particularly with the inclusion of flow baffles **119** in the shell **111** to cause the fuel to follow a lengthy, tortuous path over the membrane filter **112** to the fuel outlet **122**.

Depending upon the requirements of the deoxygenator **110**, the tubes **113** may be constructed either entirely of the material forming the membrane filter **112** or they may comprise a micro-porous structural substrate having a thin exterior layer or coating of the membrane filter material as shown in FIG. **4**. If the tubes **113** include a structural substrate, they may conveniently be porous sintered steel or other similar suitable material.

The membrane filter material is preferably PTFE having a thickness of 2 mils or less, and preferably 1 mil or less. The PTFE is available from various sources, including E. I. DuPont de Nemours of Delaware under the registered trademark "Teflon". The PTFE may be overlaid on the substrate of tubes **113** by one of several known techniques.

As generally understood from the discussion of the test system of FIG. **3**, fuel **130** stored in reservoir **132** normally contains dissolved oxygen, possibly at a saturation level of 70 ppm. The fuel **130** is drawn from reservoir **132**, typically by a pump **140**, and is connected via conduit **175** and valve **136** to the fuel inlet **120** of deoxygenator **110**. The pressure applied by pump **140** aids in circulating the fuel **130** through the deoxygenator **110** and other portions of the system. As the fuel **130** passes over the surface of membrane filter(s) **112**, the oxygen is selectively removed into and through the membrane **112** and into the interior of tubes **113**. The deoxygenated fuel flows from the fuel outlet **122**, via conduit **177**, to heat exchange sub-systems **106**, and to the ECD **104**, such as the injectors of a gas turbine engine. A portion of the deoxygenated fuel may be recirculated, as represented in broken line, by conduit **179** to either the deoxygenator or, more likely, the reservoir **132**. Any fuel leakage through the membrane filter **112** and the removed oxygen within the tubes **113** are evacuated from the deoxygenator **110**, by means such as a vacuum or aspirating pump **158**, via oxygen outlet **124** and conduit **181** connected to the reservoir **132**. This controlled removal of any fuel leakage prevents it from entering the environment and possibly posing a safety risk.

As discussed with respect to FIG. **8**, control of the oxygen partial pressures on opposite sides of the membrane filter **112** can beneficially affect the rates of deoxygenation and thus, space velocities, SV. The use of a relatively reduced pressure (partial vacuum) on the removed oxygen side aids this parameter, as does an elevation of fuel temperature to about 200–250° F. on the fuel side. The latter serves to relatively increase the oxygen partial pressure by thermally liberating oxygen. An increase in the pressure of the oxygenated fuel will not have a significant benefit because it won't significantly change the oxygen partial pressure difference across the membrane or increase the membrane's permeability. Importantly, care must be taken to not increase the pressure to a level that either damages the membrane filter **112** and/or tubes **113** or forces the fuel through the membrane. In lieu of reducing the oxygen partial pressure by removing oxygen with a vacuum pump, it is also possible to displace and remove oxygen using a nitrogen purge and accomplish the same result.

Although the invention has been described and illustrated with respect to the exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A method for removing dissolved oxygen from a liquid fuel in the fuel system of an energy conversion device, comprising the steps of:

(a) disposing a selected filter membrane in a deoxygenation chamber in the fuel system to divide the chamber into a fuel region and a removed oxygen region on opposite sides of the membrane filter;

(b) flowing fuel into the fuel region of the deoxygenation chamber and into contact with a fuel-side surface of the filter; and

(c) controlling the difference of partial pressures of oxygen across the membrane, thereby to regulate the driving force for moving oxygen through the membrane exclusive of the fuel to deoxygenate the fuel.

2. The method of claim **1** comprising the steps of:

(a) substantially continuously flowing fuel into contact with the filter membrane to substantially continuously deoxygenate the fuel;

(b) substantially continuously removing deoxygenated fuel from the fuel region of the deoxygenation chamber; and

(c) substantially continuously removing oxygen from the removed oxygen region of the deoxygenation chamber.

3. A fuel deoxygenator for removing dissolved oxygen from a liquid fuel in the fuel system of an energy conversion device, comprising a membrane filter disposed in the fuel system and positioned for liquid fuel to flow into contact with a fuel-side surface of the filter, the membrane filter being capable of removing oxygen from the fuel to a level at least below that at which significant coking occurs.

4. The deoxygenator of claim **3** wherein the membrane filter passes oxygen molecules and excludes the liquid fuel sufficiently to remove oxygen from the fuel to a level at least below about 20 ppm.

5. The deoxygenator of claim **4** wherein the membrane filter removes oxygen from the fuel to a level below about 10 ppm.

6. The deoxygenator of claim **5** wherein the membrane filter removes oxygen from the fuel to a level of about 5 ppm.

7. The deoxygenator of claim **5** wherein the membrane filter reduces the dissolved oxygen concentration in the fuel from saturation to less than about 10 ppm in a single pass of the fuel over the filter at a liquid space velocity of at least 100 h^{-1}.

8. The deoxygenator of claim **3** wherein the membrane filter is from the family of polytetraflouroethylene compounds.

9. The deoxygenator of claim **8** wherein the membrane filter reduces the dissolved oxygen concentration in fuel from saturation to less than about 10 ppm in a single pass of the fuel over the filter at a liquid space velocity of at least $100h^{-1}$.

10. The deoxygenator of claim **8** wherein the membrane filter is disposed on the surface of a porous substrate.